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TITLE PAGE

Title: Food Stress Interactions between the Argentine Ant (*Linepithema humile*) and Urban Tree Dwelling Arthropods in Relationship to Structural Invasions

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Acknowledgments

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This report was submitted in fulfillment of DPR contract 98-0282 and project title *Food Stress Interactions between the Argentine Ant (Linepithema humile) and Urban Tree Dwelling Arthropods in Relationship to Structural Invasions* by the University of California under the sponsorship of the California Department of Pesticide Regulation. Work was completed as of March 31st, 2000.

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Abstract

Because of it's ability to detect trends in data, time series analysis was used to evaluate factors related to ant invasions in a residential housing project. The residential development - Student Housing [University Village Albany (UVA), California] for the University of California at Berkeley - consists of 104 apartment buildings on a 58-acre site. Ant complaint data has been collected on the UVA site from 1969 through 1997. Complaint data collected consist of the building number, apartment number or street address, and date (mm/dd/yy) of the complaint. Each complaint was verified by the campus pest control operator that applied the ant control measures and only valid *Linepithema humile* (Mayr) complaints were included in the data set. Environmental factors (rainfall and temperature) were also obtained from a weather station near the site (Richmond, California). *L. humile* makes a shallow nest that is easily flooded and it has been theorized that this flooding forces the ants into structures for refuge from the fall/winter rains, It has also been postulated that *L. humile* is invading structures in search of water or to avoid late summer high temperatures. Statistical analysis showed no direct correlation between monthly rainfall averages and ant invasions or between average monthly temperature and ant complaints.

Ant populations were monitored on the site using bole counting of trailing ants on several species of trees. Monthly ant counts (ants/hour) were compared for A.M. vs. P.M. and across months. Ants/hours is extrapolated from bole counts of ants returning to the nest during a set period of time. The time spent counting ants is based on the number of ant trail found on the tree, No significant differences were found between A.M. and P.M. bole counts ($F = 2.84$, d.f. = 1, 1205, $p = 0.092$). Temperatures on the site rarely drop below 40°F (4.4°C) or above 90°F (32.2°C) compared to more inland sites in California, where temperatures can routinely drop below 30°F (-1.1°C) and exceed 102°F (38.8°C). However, we found significant differences in ant counts between months using pair-wise comparisons ($F = 22.22$, d.f. = 11, 1205, p 10.0001). Ant counts for August and September were significantly different from other months and October was significantly different from all months but November and July. Sampling of honeydew production in '99 showed that higher levels were directly related to time of year.

In addition three species of trees (*Pinus radiata* (D. Don), *Platanus x acerifolia* (Willd.), and *Ulmus parvifolia* (Jacq.)) were selected and analyzed for differences among those species. These species of trees are closely associated with apartment buildings/quads that have the highest level of ant complaints across the initial data set (1969 – 1997). Significant differences in ants/hours were found between these tree species ($F = 11.96$, d. f. = 14,413, $p < 0.0001$). Sampling of honeydew droplets from these trees showed that higher counts of foraging ant were correlated with trees that had higher densities of honeydew droplets.

We theorize that Argentine ant seasonal movement is related to food stress and changes in the availability of honeydew producers. There are species of homopterans (aphids, scales, and pysllids) known to be associated with trees. Several of these homopterans were collected in initial samples taken from trees with trailing ants: the oleander scale, *Aspidiotus nerii* (Bouche) was collected from *Acacia melanoxylon* (R.Br.) (blackwood acacia), European elm scale, *Gossyparia spuria* (Modeer) was collected from *Ulmus parvifolia* (Chinese elm), the irregular pine scale, *Toumeyella insignicola* (Ferris) was collected from *Pinus radiata* (Monterey pine),

the brown *soft* scale, Coccus *hesperidum* (L.) and the common black scale, *Saissetia oleae* (Olivier) was collected from *Cedrus deodara* (G.Don) (Deodar cedar).

This report provides answers to some of the basic ecological questions still surrounding this ant species and evidence that structural invasions by Argentine ants involve a complex biological relationship that contains more ecological factors than just environmental conditions.

Summary

The Argentine ant, *Linepithema humile* (Mayr), is a common invader of residential and commercial structures. *L. humile* makes a shallow nest that is easily flooded and it has been theorized that this flooding forces the ants into structures for refuge. It has also been postulated that *L. humile* is invading structures in search of water or to avoid high temperatures.

Time series analysis was used to evaluate factors related to ant invasions in a residential housing project. The residential development currently consists of > 61 buildings on a 5%acre site. Ant complaint data have been collected on the site for 28 years. Environmental factors were also obtained from a weather monitoring station near the site. Statistical analysis of the data showed no direct correlation between environmental factors and structural invasions.

We believe that seasonal movement of Argentine ants is related to food stress and changes in the availability of honeydew producers. Monthly ant counts on selected trees showed seasonal differences in numbers of foraging ants. These differences appear to correspond with population changes in honeydew producers in trees. Honeydew production on the Chinese elm, *Ulmus parvifolia* , - based on droplet density monitoring - was at the highest levels during September, October, and early November. The higher levels of honeydew production were correlated with increased number of foraging ants on those trees. A soft scale, *Gossyparia spuria* was collected from *U. parvifolia*. This scale over-winters as a second-instar nymph and is known to produce excessive amounts of honeydew in the summer and early fall. Foraging ant populations on several other species of trees on site follow a similar pattern of high activity in the summer tapering off in late fall or early winter. Honeydew production by tree dwelling arthropods begins to taper off in October and reaches very low levels by late November on *U. parvifolia*. By late November, the minimum temperatures in the San Francisco Bay Area begin to drop close to the 50°F level corresponding to minimum temperature thresholds (10°C) for some tree-dwelling arthropods (Savopoulou-Soultani 1997).

This report provides answers to some of the basic ecological questions still surrounding this ant species. This allows us to attempt to determine how Argentine ant populations increase in the urban environment with the underlying goal of using ecological patterns of food stresses (biological and environmental) to develop effective IPM strategies, It also provides evidence that structural invasion by Argentine ants involves a biological relationship that is much more complex than was previously believed. We believe that this relationship contains many more facets than just physical environmental conditions, such as, temperature and rainfall.

Introduction

The Argentine ant, *Linepithema humile* (Mayr), was first introduced from Brazil or Argentina into the United States in ca. 1891 and into California in ca. 1905 (Baker et. al. 1985). According to Knight and Rust (1990), this ant is the most widespread pest in populated areas of California with a host range that extends from the Mexican border north to Humboldt County and east to the Sierra Nevada mountain range. This ant is ranked 1st among insect pests found in the urban environment in coastal and Southern California (Holway 1999). Argentine ants commonly invade structures within the urban environment. As a result of this behavior, there is an increased potential for human exposure and environmental contamination from increased pesticide use.

There are several hypotheses describing why Argentine ants invade structures:

- Environmental factors (rainfall, temperature, etc) may drive the ants into structures.

- Food stresses caused by a seasonal reduction in honeydew producing arthropods may force the ant to forage in structures for alternative food sources.

- A combination of environmental and biological factors,

- Ant invasions are simply a result of random foraging and not related to either environmental or extrinsic biological factors.

The negative influence Argentine ants have on the biological control of arthropods in agricultural settings is well-documented (Bartlett 1961, Flanders 1958, Markin 1970, Nixon 1951, Way 1963). In addition to work in agricultural systems, a limited body of work has been done in "natural" settings (Holway 1999 and 1995, Human et. al. 1998, Ward 1987). For example, Ward (1987) examined population dynamics and distribution in natural habitats around the University of California at Davis, CA. But, the population dynamics and tropic interactions between Argentine ants and their food sources within urban environments are poorly understood, The concept of Integrated Pest Management (IPM) is based on a thorough understanding of the system and the biology of the pest species.

The overall objectives for this study are:

1.) To determine relationships between food sources, environmental conditions, and home invasions of Argentine ants, determining phenology of major honeydew producing insects and natural enemy complexes.

2.) To develop and refine sampling methods (bole and trail counts, pitfall traps, monitored bait stations, and visual site surveys) for determining population densities and distributions of Argentine ants in urban environments.

3.) To develop and evaluate IPM control strategies for Argentine ants in urban environments.

a. using natural enemies to manage honeydew producing arthropods.
b. using landscape plantings.
c. using ant exclusion and baiting technology - including evaluations of baits types (proteinous or sucrose), seasonal timing, and placement of insecticidal baits.

Results

Objective 1.) To determine relationships between food sources, environmental conditions, and home invasions of Argentine ants.

Part A. Complaints at University of California Student housing facility.

A complaint database was developed on the Argentine ant at the University of California Student housing facility (UVA) in Albany, CA. The database started in April of 1969 and continued through December 1997. This database included the following information: the building numbers, apartment number or street address, and date (mm/dd/yy) of the complaint. Each complaint was verified by the campus pest control operator that applied the ant control measures and only valid *L. humile* complaints were included in the data set. Complaint data were formulated into monthly averages across the initial data set (1969 - 1997). Environmental data were obtained from the U.C. Statewide Integrated Pest Management Project's California *Weather Database* using NCDC station # 7414 in Richmond, California. Daily precipitation and temperatures (min & max) were recorded (April 22 1969 - December 3 1, 1997) in this database. The data showed a strong "seasonal trend" in both monthly rainfall averages and in monthly ant complaints. Ant complaints begin rising in July while rainfall does not rise sharply until late September or early October (Figure 1). Rainfall lagged behind ant complaints by approximately three months.

The entire database (1969 - 1998) was analyzed using time series analysis to determine if there is any direct correlation between ant complaints and environmental factors. The Systat 8.0 Statistical Package for Windows was used to analyze complaint and environmental data using time series analysis (Systat 8.0 for windows 1999). The time-domain model in time series analysis represents a series as a function of the previous points in the same series (or as a systematic trend through time) and can tit complex patterns of a time series with very few parameters. The autocorrelation function in the model allows for the comparison of each time point in a time series to previous points. The analysis was conducted using twelve-month periodicity. If the autocorrelation in a time series at lag 1 is high (>0.6), the values are highly correlated with the value at the previous time point. If the autocorrelation is high at lag 12 for data that was collected monthly, then each month is highly correlated with the same month from the previous year. In our data set, a lag of 1 would be defined as the previous month and a lag of twelve would be same month from the previous year. The data showed strong positive correlation between monthly values for complaints on a 12-month lag and a weaker negative correlation between monthly values that were lagged by 6 months (Figure 2). This autocorrelation plot shows that there is a strong seasonal component in the complaint data. For example, ant complaints in September from year to year are positively correlated and negatively correlated with January from year to year. Figures 3 show a similar seasonal component in the rainfall data (monthly average temperatures (max & min) also showed similar correlations). Cross-correlation function allows for the investigation of relationships between two different data series and any time delays associated with the relationships. The cross-correlation analysis showed that ant complaints and rainfall are seasonally strongly correlated (Figure 4). But when the seasonal effect is removed using a multiplicative adjustment. the strong correlation between ant complaints and rainfall is lost (Figure 5). The multiplicative adjustment model uses a proportional seasonal factor that is a percentage of the level of the series by which each point in the series is divided. Time series analysis of this data set showed no direct correlation between monthly rainfall averages and ant invasions or between average monthly temperature and ant complaints.

Part B. Monitoring of Trees – Honeydew Sampling.

UVA site was used to develop and refine honeydew-sampling methods. No other urban sites were selected for evaluation during the first year of this project. The 58-acre (UVA) site has 564 apartments in 61 structures. The apartment buildings on site are designed with inner quads and are surrounded by an irrigated mature landscape (lawn and trees). There are ≈ 700 trees with six major species: one Eucalyptus: Ironbark *(Eucalyptus sideroxylon* (A.&m.)), one pine: Monterey pine (*Pinus radiata*), one sycamore: London planetree *(Platunus x acerifolia*), one acacia: Blackwood acacia *(Acacia melanoxylon)*, one cedar: *(Cedrus deodaru)* and one elm: Chinese elm (*Ulmus parvifolia*). Each individual tree on the site has been uniquely numbered. Figure 6. shows 1/18th of the total UVA site with buildings present and tree species indicated through color-coding. Three of the six major species on the Albany Village site have been selected for bi-weekly monitoring of honeydew production by tree dwelling arthropods: *P. radiuta, Platanus x acerifolia*, and *U. parvifolia*. Selection of tree species used for honeydew sampling was based on the complaint database and proxsymmetry to the apartment buildings on the site. A total of 48 trees have been selected for honeydew monitoring *(20 P. radiata,* 14 *Platunus x acerifolia*, and 14 *U. parvifolia*) on the Albany Village site. All trees were selected at random from on-site populations for each species. Honeydew monitoring was done using yellow water sensitive cards (7.6 x 5.2 cm cards) on which honeydew produces distinct blue dots. These monitoring cards are manufactured for use as insecticide spray droplet monitoring devices (Spraying Systems, Wheaton, IL.). Four cards were placed ≈ 60 cm below terminal branches using a wire hanger in the cardinal directions on *Plutunus x acerifolia*, and *U. parvifolia.* The cards were deployed from 10:00 A.M. to 2:00 P.M. every other week during the growing season for *Plutunus x acerifolia*, and during the entire season for *U. parvifolia*. Foraging ants on the trees were also counted using the protocol outlined for monthly counts. Honeydew monitoring for *Platanus x acerifolia* and *U. parvifolia* began the week of September 20th. There were nine sample dates for *U. parvifolia* between September 24th, 1999 and February 29th, 2000. Four of these dates (9-24, 1 O-8, 1 O-22, 11-5) were analyzed using ANCOVA in the GLM model with Systat 7.01 for windows. These dates showed correlation's between honeydew production and trailing ant foragers ($F = 9.008$, d.f. =1, 43, $p = 0.004$) and between dates ($F = 3.684$, d.f. = 3, 43, $p = 0.019$). *U. parvifolia* trees with a higher density of honeydew droplets per cm^2 had greater populations of foraging ant (see Figure 7). The homogeneity of slopes for all dates or the interaction term (ant* date) was not significant. In other words, there was no significant difference between the slopes of the regression lines for the five sample dates. Table 1. shows means and standard error for honeydew droplets (cm*) adjusted by ants for the four sampling dates.

In addition, we compared honeydew droplet densities from the four cardinal directions and found no significant differences ($F = 1.034$, d.f. = 3, 184, $p = 0.379$). Honeydew sampling on *Platanus x acerifolia* was conducted only once (September 28th) prior to the onset of leaf senescence. We found no correlation between honeydew droplets and ant counts (Figure 8).

Objective 2.) To develop and refine sampling methods for determining population densities and distributions of Argentine ants in urban environments.

The UVA site was used to develop and refine Argentine ant sampling methods. No other sites were selected for evaluation during the first year of this project. Selected trees from major tree species on the site were monitored for seasonal changes in trailing ant populations via bole counting on a monthly basis. The number of ant trails on a given tree was determined before counting, as well as, the cardinal (N, S, E, W, SW, SE, NW, and NE) direction of each trail. The total time spent counting ant trails on any one tree was 20 minutes (if the total number of ant trails was ≤4 each trail was counted for five minutes; if ant trail numberswere ≥5 then each trail was counted for 20 minutes divided by the total number of trails). Temperature and humidity were recorded at each tree location. Bole counting of trailing ants was taken twice daily (A.M. & P.M.) for a given tree on a given day. However not all of the selected trees were counted on the same day of the month. Table 2. indicates the trees species, common name, and number of each species selected for surveying. In any given tree species, a maximum of six trees was selected for bole counting of trailing ants and in three species (*Liriodendron tulipifera* (L.), *Aesculus californica* (Nutt.), and *Alnus rhombifolia* (Nutt.)) only one tree was used for bole counting of trailing ants. The number of trees selected for bole counting in a given species was limited by the number trees present on the site.

Ant populations were monitored using bole counting of trailing ants on 11 species of trees (Blackwood acacia, White alder, California buckeye, Deodar cedar, Chinese elm, Ironbark eucalyptus, Liquid amber, Lombardy popular, Monterey pine, Plane tree, and Tulip tree). Ant counts (ants/hour) were compared for A.M. vs. P.M. using SAS GLM procedure and across months using SAS Ryan-Einot-Gabriel-Welsh Q multiple range test (SAS Institute 1999). No significant differences were found between a.m. and p.m. bole counts (F = 2.84, d.f. = 1, 1205, p = 0.092). Figure 9. shows monthly averages of ants/hour for A.M. and P.M. bole counts for Argentine ants at UVA. The daily temperature regimes do not significantly effect Argentine ant trailing. These negative findings are different from findings reported by Markin (1970) where they found that morning and afternoon temperatures directly affected Argentine ant trailing. Temperatures on the UVA site rarely drop below (4.4°C) or above 90°F (32.2°C) compared to more inland sites in California, where temperatures can routinely drop below 30°F (-1.1°C) and exceed 102°F (38.8°C). However, significant differences in ant counts were found between months using pair-wise comparisons (F = 22.26, d.f. = 11, 1204, p <0.0001). Ant counts for August and September were significantly different from other months and October was significantly different from all months but July and November. Ant activity increases in May over the previous month by a factor of 1.4 and continued to climb into the summer, peaking in September with a maximum mean level of 6559 ants/hour ± 1117.98 S.E. The ANOVA results for pooled tree species data are presented in Table 3.

In addition to pooling all tree data and examining monthly differences, three species of trees (*P. radiata*, *Platanus x acerifolia*, and *U. parvifolia*) were selected and analyzed for differences among those species. These species of trees are closely associated with apartment buildings/quads that have the highest level of ant complaints across the initial data set (1969 – 1997). Figure 10 shows monthly average of trailing ants for *P. radiata*, *Platanus x acerifolia*, and *U. parvifolia*. Significant differences in ants/hour were found between these tree species ($F = 11.96$, d. f. = 14,413, $p < 0.0001$)

Ant populations and movements were also followed in two building/quad areas [(buildings 75, 76 and 77) and (buildings 55, 56, and 57)] via visual inspection. Any nest sites located during visual inspection are marked and ant-trailing activity is recorded. Movement to/from nesting sites is ranked according to the trail intensity (I 10 ants/minute = light, 11 to 20 ants/minute = medium, ≥ 21 ants/minute = heavy). All three species of trees (*P. radiata*, *Plutunus x acerifolia*, and *U. parvifolia*) selected for honeydew monitoring are closely associated with these buildings/quads. Ant populations were monitored weekly for six weeks. In general, ant populations were very mobile with weekly fluctuation in trail intensities and nest entrance points. However, the entrance points that were found going into structures did not change during the six-week evaluation period.

Objective 3.) To develop and evaluate IPM control strategies for Argentine ants in urban environments.

No IPM control strategies for Argentine ants were developed or evaluated during this phase of the project.

Discussion

This research provides answers to some of the basic ecological questions still surrounding this ant species. Traditionally, Argentine ant invasions into structures have been believed to be related to environmental factors such as rainfall and temperature (max and min).

Markin (1970) showed that Argentine ants were active at temperatures from 5” to 35” C and foraged at temperatures ranging from 10” to 30” C. Temperatures at the Albany village site rarely drop below 40” (4.4’ C) because of the moderating influences of the San Francisco Bay. But, these temperatures are close to minimum threshold temperatures for some homopterans (Arias-Reveron and Browning 1995, Jorgensen *et* al. 1981, Masters et al. 1998, Parker *et* al. 1998, Rock and McClain 1990, Walgenbach *et* al. 1988, Wang *et* al. 1997, and Yu and Luck 1988,). Most of the temperature threshold research that has been conducted to date has been on homopterans of economic importance and not on landscape pests. However, Dreistadt (1996) used a threshold of *11” C* for *Coccus pseudomagnoliarum* , the Citricola Scale, which is known for producing copious amounts of honeydew. This scale is in the same genus as the brown soft scale, *Coccus hesperidum* that was collected from *C. deodara* on the Albany village site. The temperature thresholds for the two scales are most likely similar. Honeydew monitoring on *U. parvifolia* showed that there was a definite decline in honeydew production during the fall of the year. A temperature threshold of 11” C would limit the use of this scale by Argentine ants as sources of honeydew during the fall and winter and would require that the Argentine ant locate alternative food sources. Structural invasions in the late summer have been believed to be related to temperature thresholds in the Argentine ant. Markin (1970) showed that Argentine ants stop foraging when air temperature exceeds 35” C. Under such extreme condition, the ants would preferentially forage in the early morning or at night. The results of bole counting on the Albany village shows that there is no preferential foraging at this site and most likely that would be the case for most of coastal California. It would only be in the inland and interior valleys of California where temperature thresholds for the Argentine ant would play an important role in foraging behavior.

Our results show that there are definite seasonal patterns to the foraging of Argentine ants and that structural invasion by Argentine ants involves a biological relationship that is much more complex than was previously believed. However, there are still many unanswered question that must be answered before we would have a real through understanding of foraging behavior in the Argentine ant.

Summary and Conclusions

We believe that seasonal movement of Argentine ants is related to food stress and changes in the availability of honeydew producers. Monthly ant counts on selected trees showed seasonal differences in numbers of foraging ants. These seasonal differences in foraging ants correlate well with seasonal changes in honeydew production by tree dwelling arthropods. Honeydew sampling showed that levels dropped off in the fall of the year when temperatures correspond to the minimum temperature threshold ($\approx 10°C$) for some tree-dwelling arthropods.

A more through understanding of the mechanisms behind these process will help us to develop effective IPM strategies for the Argentine ant. During this initial study, we have attempted to determine how Argentine ant populations increase in the urban environment. This research was conducted with the underlying goal of using ecological patterns of food stresses to develop move effective control strategies.

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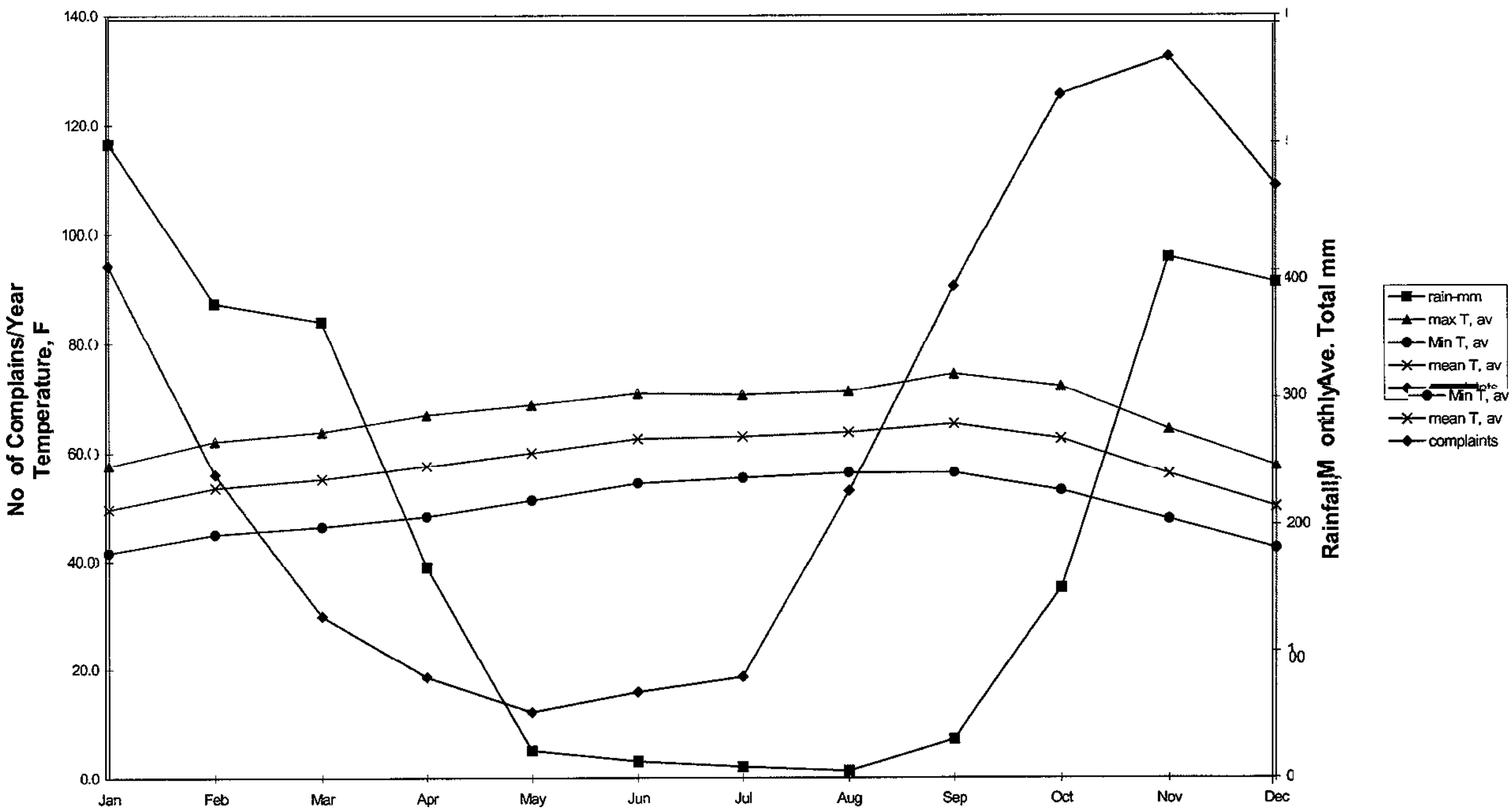
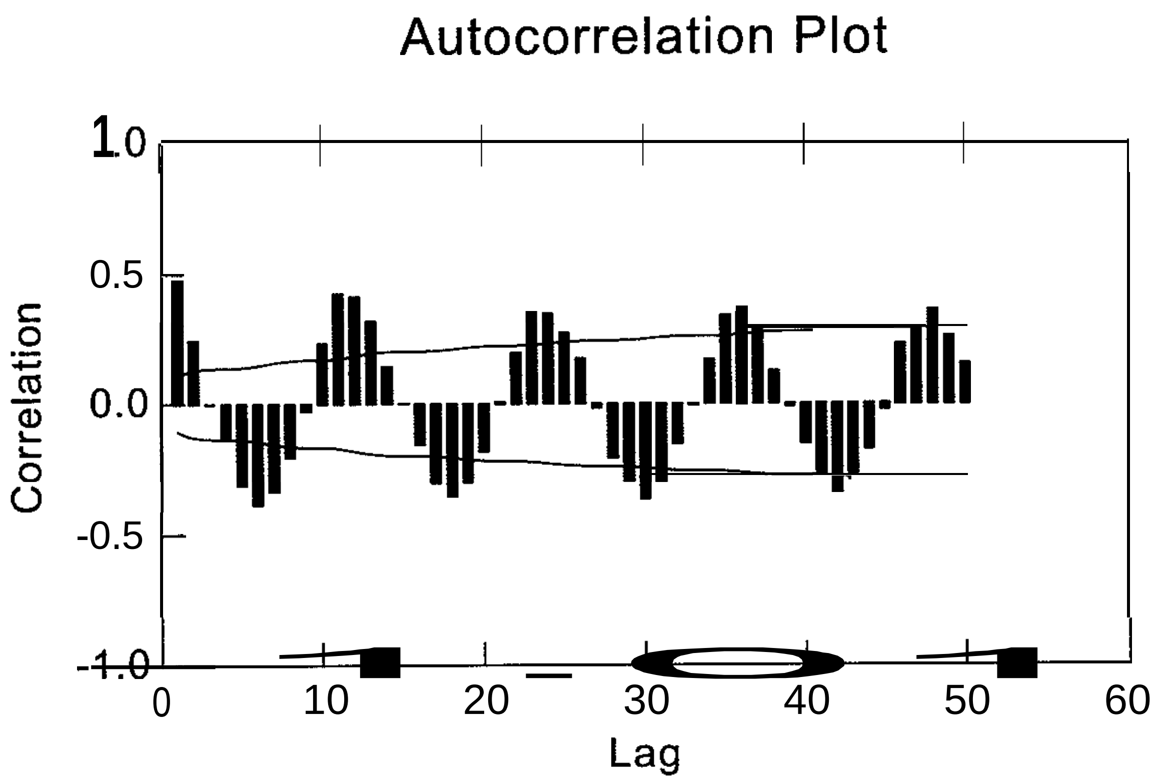
Figure 1. Monthly Averages for Argentine Ant Complaints and Weather (1969 – 1997) at the University of California, Student's Housing Facility (UVA) in Albany, California.*



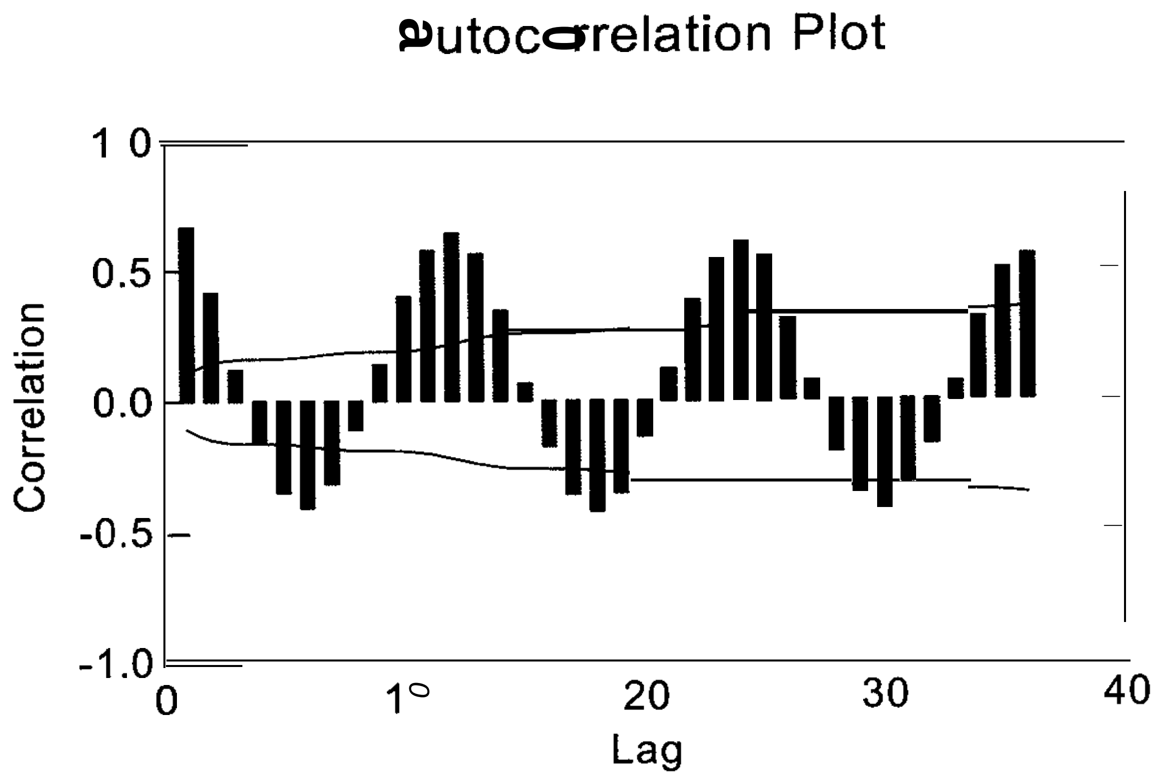
* The residential development - Student Housing [University Village Albany (UVA), California] for the University of California at Berkeley - consists of 104 apartment buildings on a 58-acre site. Ant complaint data has been collected on the UVA site from 1969 through 1997. Complaint data collected consist of the building number, apartment number or street address, and date (mm/dd/yy) of the complaint. Each complaint was verified and only valid *Linepithema humile* (Mayr) complaints were included in the data set. Environmental factors (rainfall and temperature) were also obtained from a weather station near the site (Richmond, California). For simplicity, standard error bars have been omitted from the averages.

Figure 2. Autocorrelation Plot for Monthly Argentine Ant Complaint Data (1969 – 1997) at the University of California Student's Housing Facility (UVA) in Albany, California. *



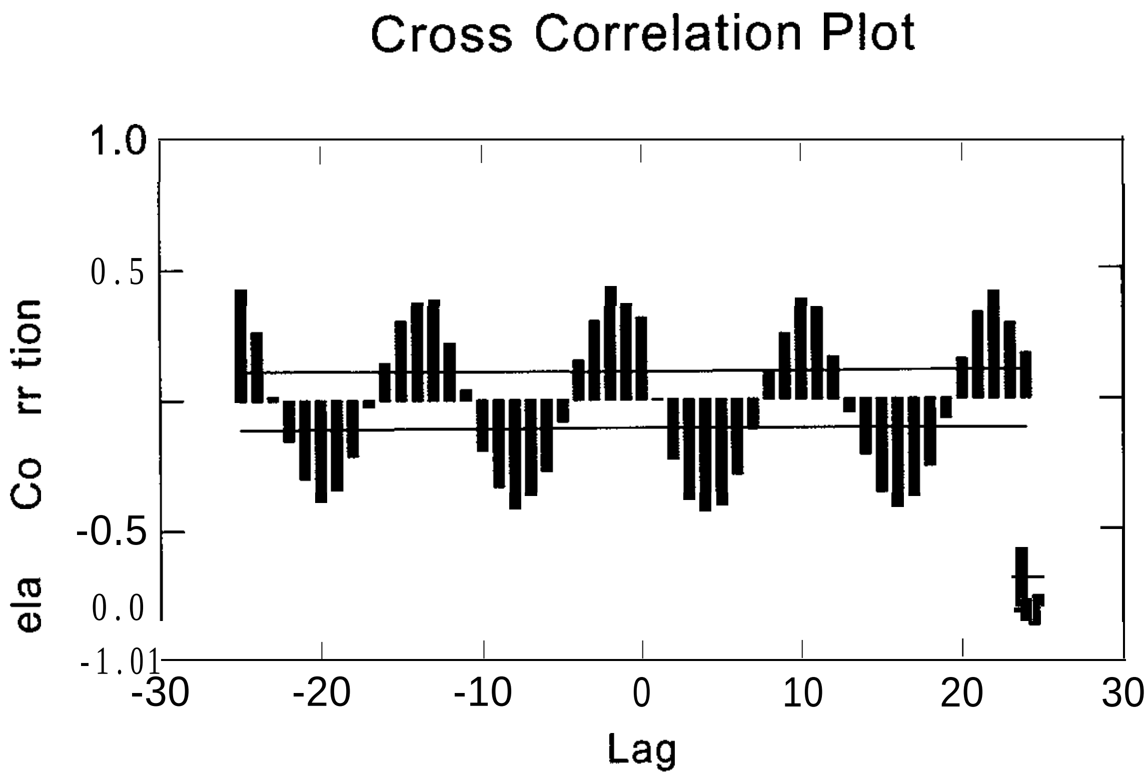
* A complaint database was developed on the Argentine ant at the University of California Student housing facility (UVA) in Albany, CA. The database started in April of 1969 and continued through December 1998. Complaint data were formulated into monthly averages across the initial data set (1969 - 1998). The curved red line approximates the 95% confidence levels for the significance of each correlation. In our data set, a lag of 1 would be defined as the previous month and a lag of twelve would be the same month from the previous year.

Figure 3. Autocorrelation Plot for Monthly Rainfall (1969 – 1997) at the University of California Student's Housing Facility (UVA) in Albany, California. *



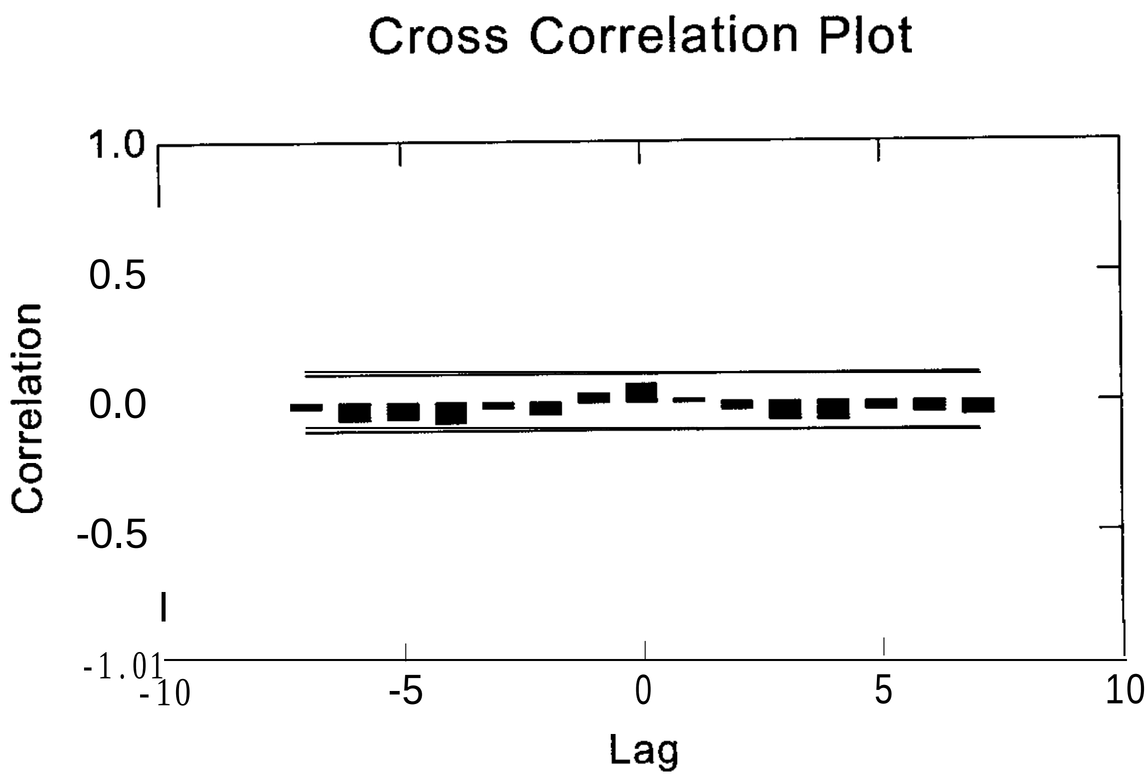
* Environmental data were obtained from the UC. Statewide Integrated Pest Management Project's ***California Weather Database*** using NCDC station # 7414 in Richmond, California. Daily precipitation and temperatures (min & max) were recorded (April 22 1969 **-** December 31, 1998) in this database. The curved red line approximates the 95% confidence levels for the significance of each correlation. In our data set, a lag of 1 would be defined as the previous month and a lag of twelve would be the same month from the previous year.

Figure 4. Crosscorrelation Plot for Monthly Argentine Ant Complaints and Rainfall (1969 – 1998) at the University of California Student's Housing Facility (UVA) in Albany, California. *



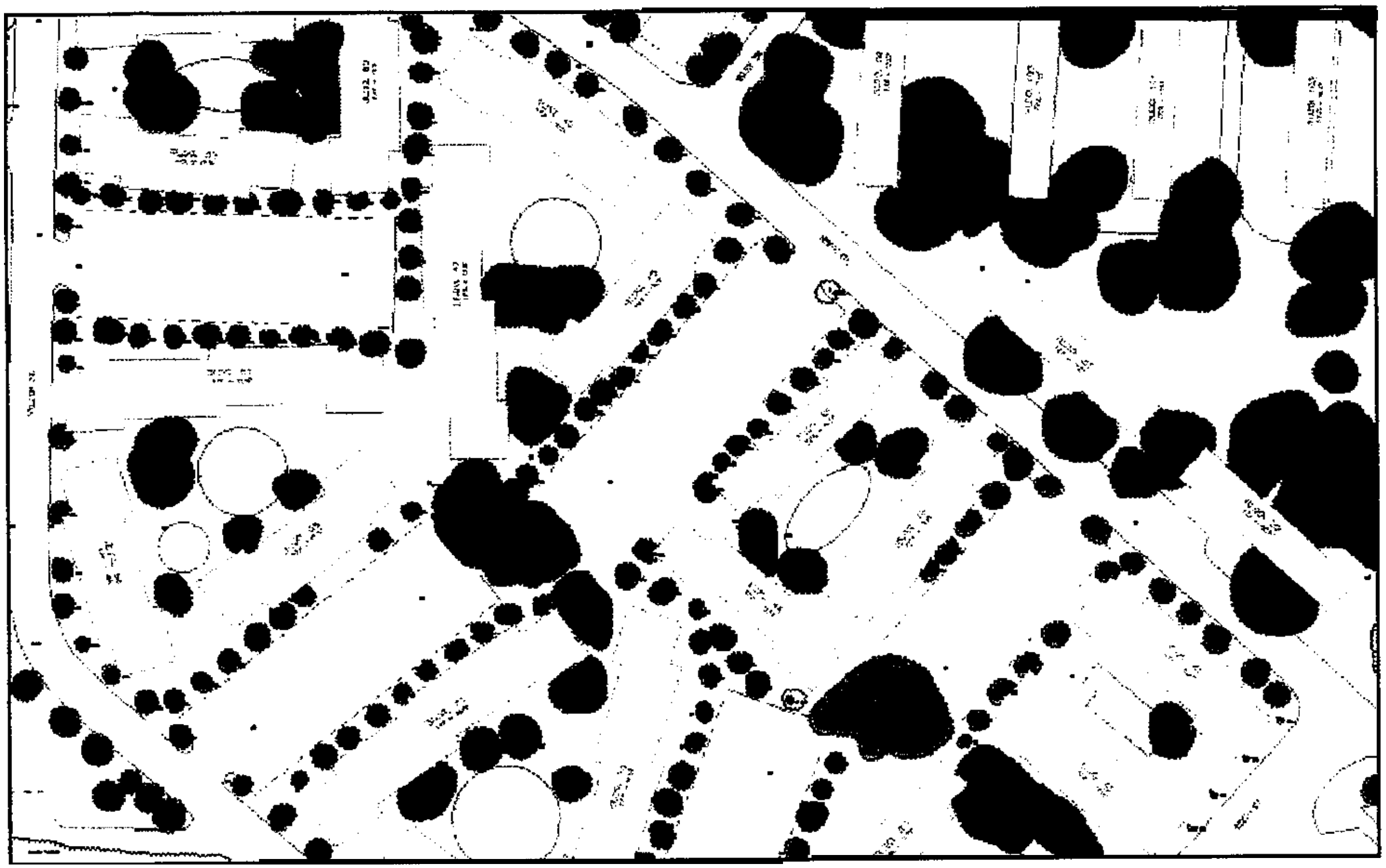
* Complaint database was developed on the Argentine ant at the University of California Student housing facility (UVA) in Albany, CA. The Database started in April of 1969 and continued through December 1998. Complaint data were formulated into monthly averages across the initial data set (1969 - 1998). Environmental data were obtained from the U.C. Statewide Integrated Pest Management Projects ***California Weather Database*** using NCDC station # 7414 in Richmond, California. Daily precipitation and temperatures (min & max) were recorded (April 22 1969 - December 31, 1998) in this database. The red line approximates the 95% confidence levels for the significance of each correlation. In our data set, a lag of 1 would be defined as the previous month and a lag of twelve would be the same month from the previous year.

Figure 5. Crosscorrelation Plot for Monthly Argentine Ant Complaints and Rainfall (1969 – 1998) at the University of California Student's Housing Facility (UVA) in Albany, California with a Multiplicative Adjustment.*



* A complaint database was developed on the Argentine ant at the University of California Student housing facility (UVA) in Albany, CA. The database started in April of 1969 and continued through December 1998. Complaint data were formulated into monthly averages across the initial data set (1969 - 1998). Environmental data were obtained from the U.C. Statewide Integrated Pest Management Project's ***California Weather Database*** using NCDC station # 7414 in Richmond, California. Daily precipitation and temperatures (min & max) were recorded (April 22 1969 - December 31, 1998) in this database. The curved red line approximates the 95% confidence levels for the significance of each correlation. In our data set, a lag of 1 would be defined as the previous month and a lag of twelve would be the same month from the previous year. The multiplicative adjustment model uses a proportional seasonal factor that is a percentage of the level of the series by which each point in the series is divided.

Figure 6. Typical layout of buildings and landscape at the University of California Student's Housing Facility (UVA) in Albany, California. *

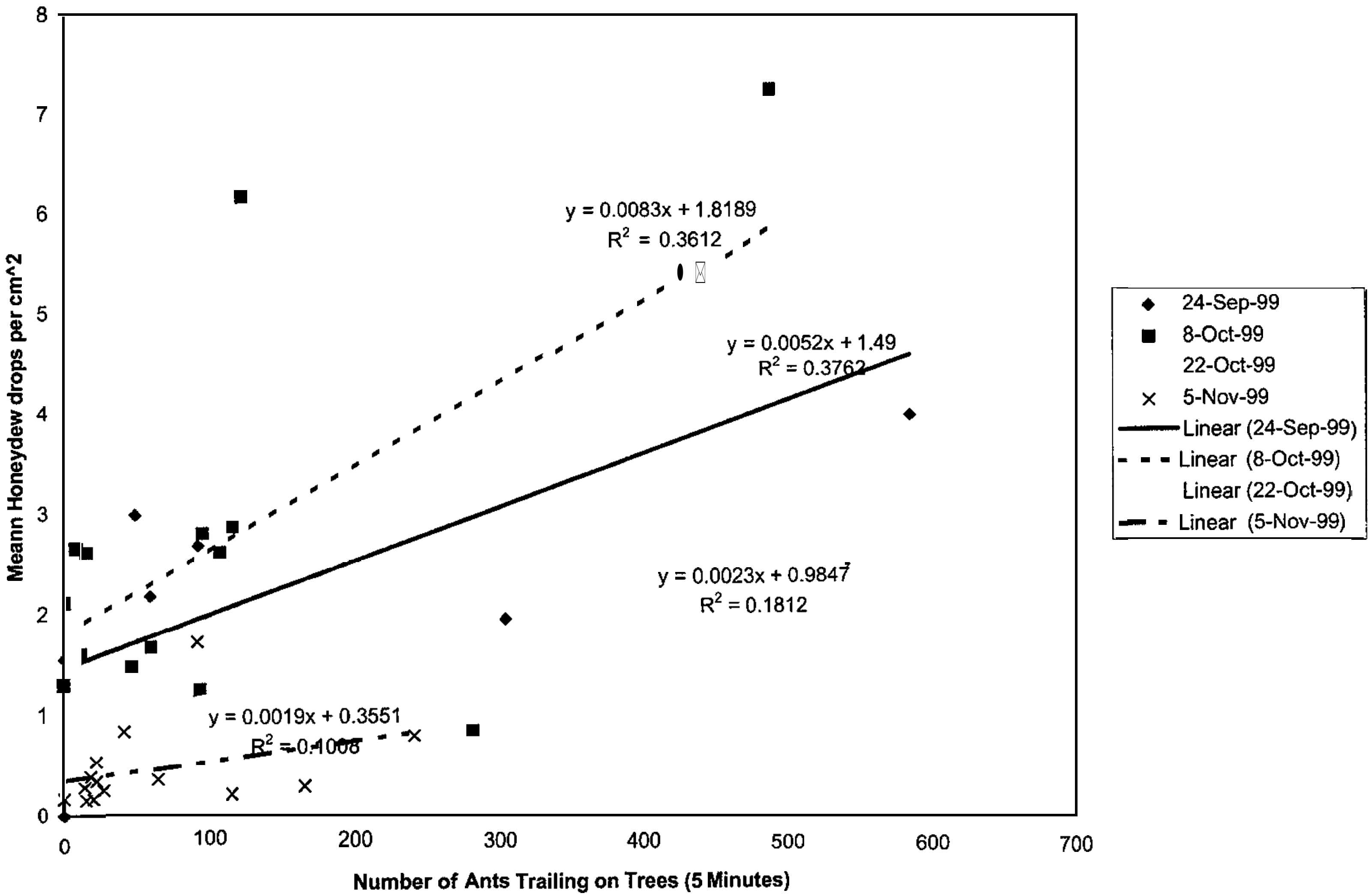


Tree Species Legend

- *Pinus radiata*
- *Ulmus parvifolia*
- *Eucalyptus sideroxylon*
- *Acacia melanoxylon*
- *Platanus x acerifolia*

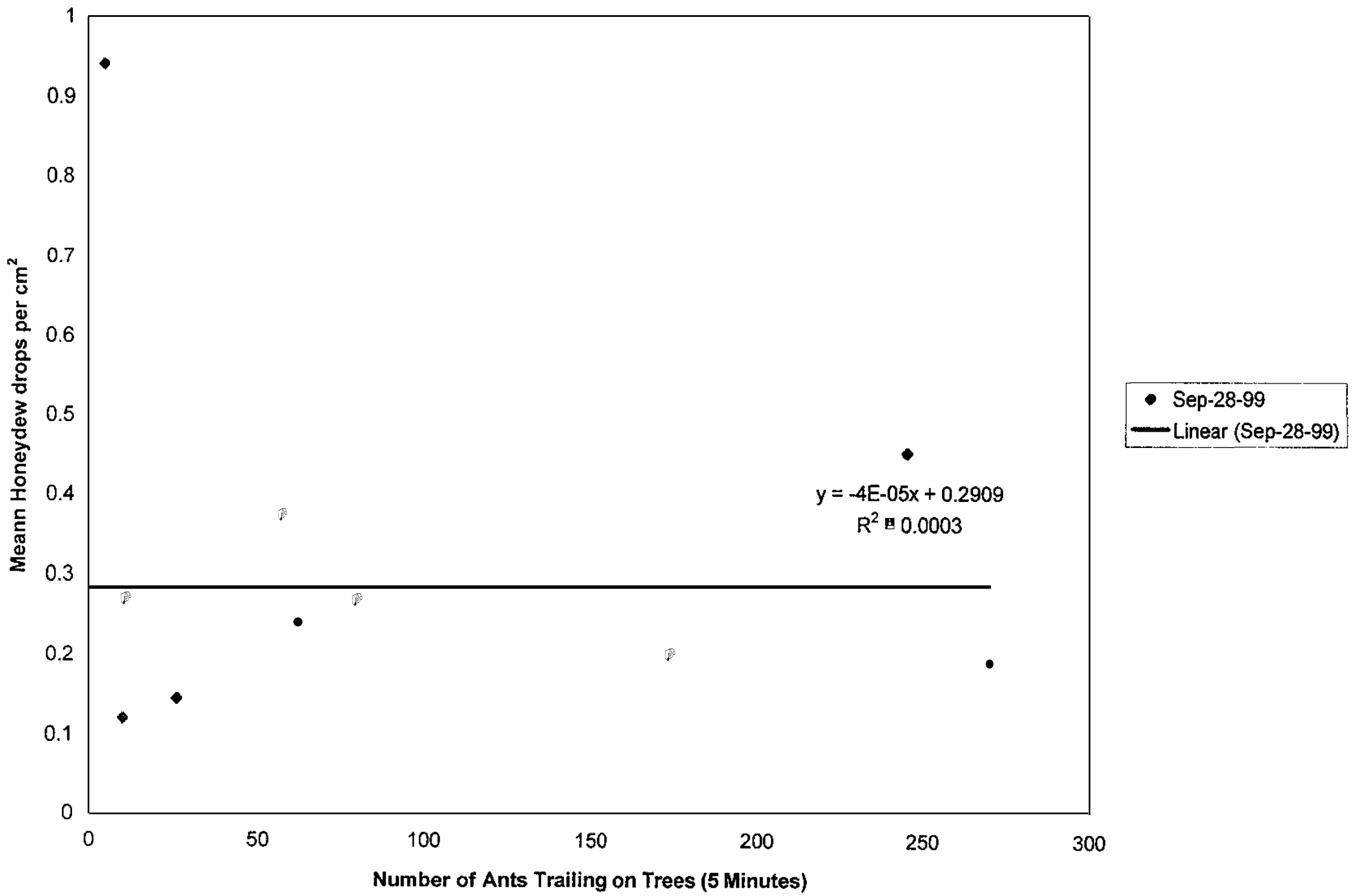
* ne typical layout of buildings ıd dsca (stree ee ar ope spa lawn areas and mat
oecimen trees. Jagged circle nd te tre anopi (c or de acco nd rectangular shap
dicate apartment buildings.

Figure 7. Linear Regressions for Honeydew Droplets vs. Trailing Argentine Ants on selected *Ulmus parvifolia* at the University of California Student's Housing Facility (UVA) in Albany; California.



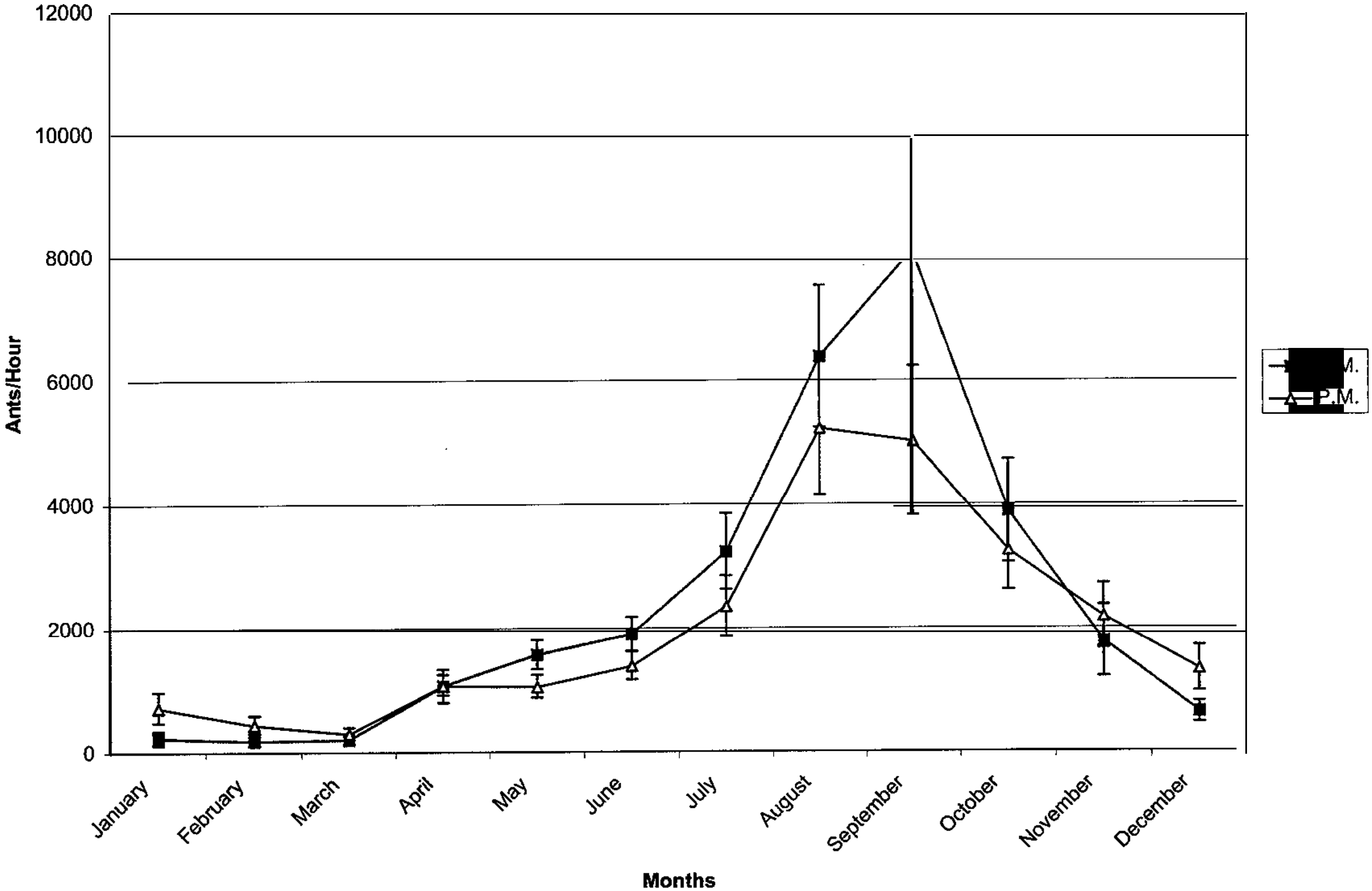
Honeydew monitoring was done using yellow water sensitive monitoring cards (7.6 x 5.2 cm cards) on which honeydew produces distinct blue dots. Four cards were placed = 60 cm below terminal branches using a wire hanger in the cardinal directions on *U. parvifolia.* The cards were deployed from 10:00 A.M. to 2:00 P.M. on sampling dates. The total time spent counting ant trails on any one tree was 20 minutes (if the total number of ant trails was ≤ 4 each trail was counted for five minutes; if ant trail numbers were ≥ 5 then each trail was counted for 20 minutes divided by the total number of trails).

Figure 8. Linear Regression for Honeydew Droplets vs. Trailing Argentine Ants on selected *Platanus* x *acerifolia* at the University of California Student's Housing Facility (UVA) in Albany, California.



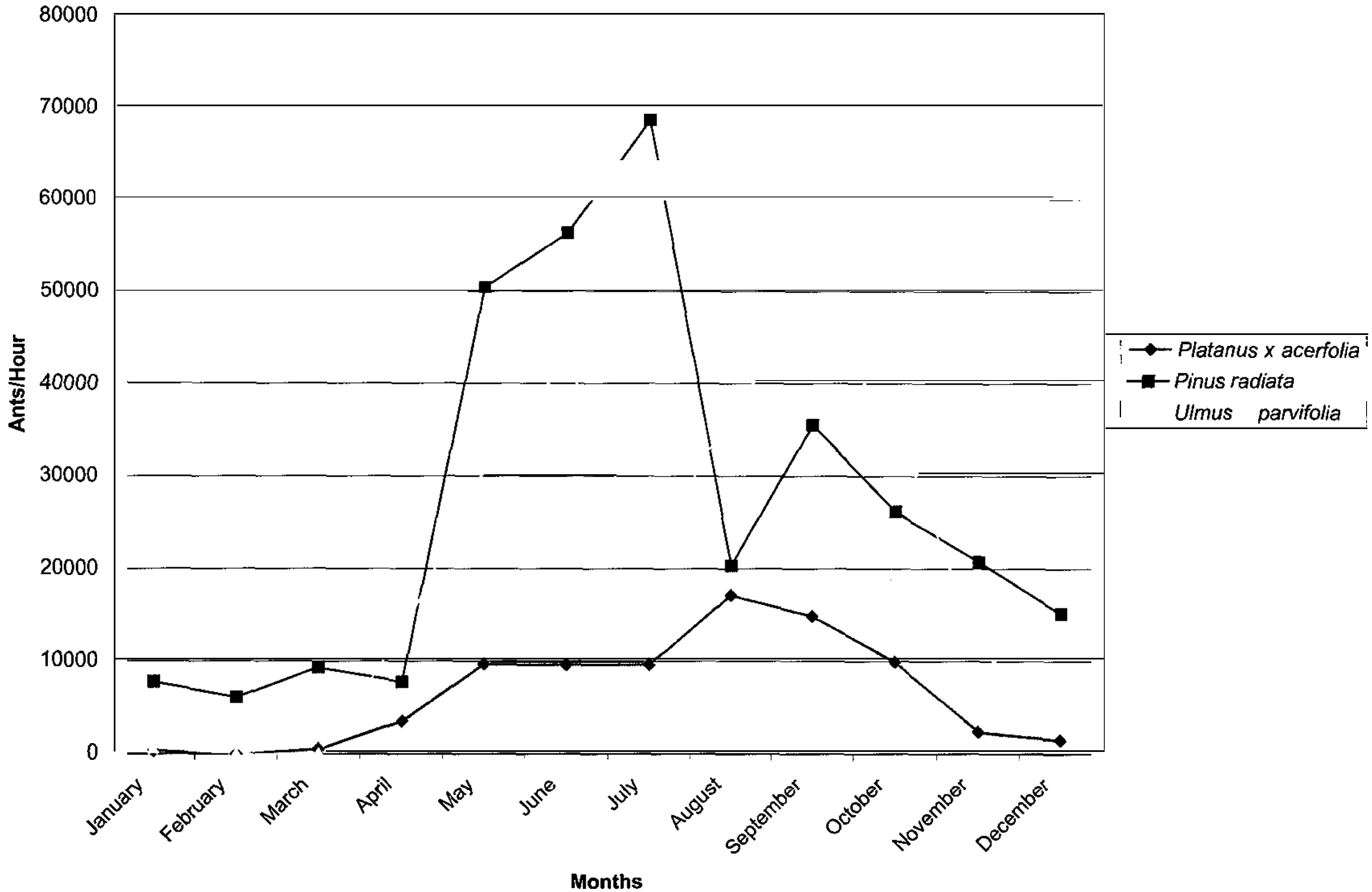
Honeydew monitoring was done using yellow water sensitive insecticide spray droplet monitoring cards (7.6 x 5.2 cm cards) on which honeydew produces distinct blue dots. Four cards were placed ≈ 60 cm below terminal branches using a wire hanger in the cardinal directions on *Platanus x acerifolia.* The cards were deployed from 10:00 A.M. to 2:00 P.M. on sampling dates. The total time spent counting ant trails on any one tree was 20 minutes (if the total number of ant trails was ≤ 4 each trail was counted for five minutes; if ant trail numbers were ≥ 5 then each trail was counted for 20 minutes divided by the total number of trails).

Figure 9. Monthly Averages (A.M vs. P.M.) Trailing Argentine Ants at the University of California Student's Housing Facility (UVA) in Albany, California.*



* Ant counts from 1998 – 1999 were pooled for monthly averages starting in May 1998 and ending in September 1999. All ant counts were conducted at the University of California Student's housing facility (UVA) in Albany, CA. between 8:00 A.M. and 4:00 P.M. No bole counting of trailing ants on these tree species were conducted during in September 1998, October 1999, November 1999, and December 1999.

Figure 10. Monthly Averages for Trailing Argentine Ants on Specific Tree Species at the University of California Student's Housing Facility (UVA) in Albany, California.*



* Ant counts from 1998 – 1999 were pooled for monthly averages starting in May 1998 and ending in September 1999. All ant counts were conducted at the University of California Student's housing facility (UVA) in Albany, CA between 8:00 A.M. and 4:00 P.M. No bole counting of trailing ants on these tree species were conducted during i September 1998, October 1999, November 1999, and December 1999. For simplicity, standard error bars have been omitted from the averages.

Table 1. Mean Honeydew Droplet Densities (cm^2) on Selected *Ulmus parvifolia* at the University of California Student's Housing Facility (UVA) in Albany, California.*

Sampling Dates[a]	Honeydew Droplet Density (cm^2)	± S.E.[b]	N[c]
September 24, 1999	2.934	0.356 a b	14
October 8, 1999	2.534	0.293 a	14
October 22, 1999	1.266	0.330 b c	14
November 5, 1999	0.614	0.421 c	9

Honeydew monitoring was done using yellow water sensitive insecticide spray droplet monitoring cards (7.6 x 5.2 cm cards) on which honeydew produces distinct blue dots. Four cards were placed ≈ 60 cm below terminal branches using a wire hanger in the cardinal directions on *U. parvifolia.* The cards were deployed from 1O:OO A.M. to 2:00 P.M. on sampling dates,

[a] Honeydew droplets were sampled every two weeks starting on September 24'" 1999.

[b] Means for sampling dates were compared on a pair-wise basis. Standard errors followed by the same letter in a column are not significant at a p value > 0.05 using SAS GLM procedure (Ryan-Einot-Gabriel-Welsh Q multiple range test).

[c] Number of card were pooled for total trees sampled (14 *Ulmus parvifolia* trees) on a given sampling date at the University of California Student housing facility (UVA) in Albany, California.

Table 2. Number of Trees at Albany Village Site Selected for Bole Counting of Argentine Ant (*Linepithema humile*) Populations *.

Common Names [a]	Scientific Name [b]	Number of Trees Selected [c]
Blackwood acacia	*Acacia melanoxylon*	6
White alder	*Alnus rhombifolia*	1
California buckeye	*Aesculus californica*	1
Deodar cedar	*Cedrus deodara*	3
Chinese elm	*Ulmus parvifolia*	6
Ironbark eucalyptus	*Eucalyptus sideroxylon*	6
Liquid amber	*Liquidambar styraciflua*	4
Lombardy poplar	*Populus nigra 'Italica'*	4
Monterey pine	*Pinus radiata*	6
Plane tree	*Platanus x acerifolia*	6
Tulip tree	*Liriodendron tulipifera*	1

Trees were randomly selected from the overall population of trees with trailing ants at the University of California Student's housing facility (UVA) in Albany, CA.

a Common names of trees are based on the Sunset Western Garden Book.

b Tree species were identified by Dr. Joe McBride at the University of California, Berkeley.

c The Number of trees in each species selected for bole counting was base on the overall number of that species of tree on the Albany Village site with six trees being the maximum number.

Table 3. Monthly Averages of Trailing Argentine Ant at the University of California Student Housing Facility (UVA) in Albany, California.*

Month.9	Ants/ Hr	± S.E.[b]		N[c]
January	482.60	137.8	d	88
February	317.40	82.7	d	87
March	256.80	57.8	d	88
April	915.80	157.2	c d	88
May	1330.00	151.9	c d	158
June	1659.70	179.5	c d	148
July	2770.90	386.2	b c	129
August	5804.80	781.6	a	100
September	6559.60	524.4	a	82
October	3576.60	524.4	b	68
November	2003.00	387.3	b c d	65
December	989.10	205.8	c d	88

Ant counts from 1998 – 1999 were pooled for monthly averages starting in May 1998 and ending in September 1999. All ant counts were conducted at the University of California Student housing facility (UVA) in Albany, CA. between 8:00 A.M. and 4:00 P.M.

a No bole counting of trailing ants was conducted during the month of September 1998, October 1999, November 1999, December 1999.

b Means for monthly averages were compared on a pair-wise basis. Standard errors followed by the same letter in a column are not significant at a p value > 0.05 using SAS GLM procedure (Ryan-Einot-Gabriel-Welsh Q multiple range test).

c Number of ant trail counts for a.m. and p.m. were pooled for all species of trees (Blackwood acacia, White alder, California buckeye, Dedora cedar, Chinese elm, Ironbark eucalyptus, Liquid amber, Lombardy popular, Monterey pine, Plane tree, and Tulip tree) at the University of California Student housing facility (UVA) in Albany, California.

Table 4. Monthly Averages of Trailing Argentine Ant on Selected Species of Trees at the University of California Student *Housing Facility (UVA) in Albany, California.

Month.9	Ants/ Hr	± S.E.[b]		N[c]
January	414.40	137.82	d e	32
February	172.30	82.77	e	36
March	276.00	57.84	e	36
April	675.30	157.17	d e	36
May	1378.30	151.86	c d e	66
June	1916.20	179.53	c d e	64
July	2173.60	386.27	b c d	54
August	3726.10	781.59	a b	36
September	4219.80	1117.80	a	36
October	2937.50	524.44	a b c	36
November	1081.10	387.30	d e	32
December	804.90	205.65	d e	36

Ant counts from 1998 – 1999 were pooled for monthly averages starting in May 1998 and ending in September 1999. All ant counts were conducted at the University of California Student housing facility (UVA) in Albany, CA. between 8:00 A.M. and 4:00 P.M.

a No bole counting of trailing ants was conducted during the month of September 1998, October 1999, November 1999, December 1999.

b Means for monthly averages were compared on a pair-wise basis. Standard errors followed by the same letter in a column are not significant at a p value > 0.05 using SAS GLM procedure (Ryan-Einot-Gabriel-Welsh Q multiple range test).

c Number of ant trail counts for a.m. and p.m. were pooled for three species of trees (Chinese elm, Monterey pine, and Plane tree) at the University of California Student housing facility (UVA) in Albany, California.